Output Standing Wave Ratio (SWR) Test Using the TEGAM 1830A RF Power Meter

When using a power meter that references to a 50 MHz, 1 mW output power reference it is important to know that the 50 MHz reference is within the specified performance limits. The TEGAM Model 1830A RF Power Meter coupled with a thermistor power sensor (also known as a thermistor mount) can accurately measure the SWR of a 50 MHz reference. By utilizing a unique function that most modern power meters do not offer; the 1830A allows the user to change the value of the thermistor mounts terminating resistance. Utilizing this method for measuring source match works well because it presents the source with two distinctly different values of Γ_{Load} which allows accurate measurement of the power absorbed under two different conditions. This application note will explain how we make this SWR measurement with the 1830A and a thermistor mount.

It is first important to understand how a thermistor mount operates and why by simply changing the resistance that the reference resistor balances at can accurately determine SWR.

Figure 1 shows how a DC bridge circuit maintains series resistance of two thermistors at the nominal bridge resistance, typically 200 Ω. The thermistors(T) are matched so each thermistor is biased at 100 Ω. The thermistors are in parallel for the RF signal path, since each are biased at 100 Ω the pair make a good 50 Ω termination.

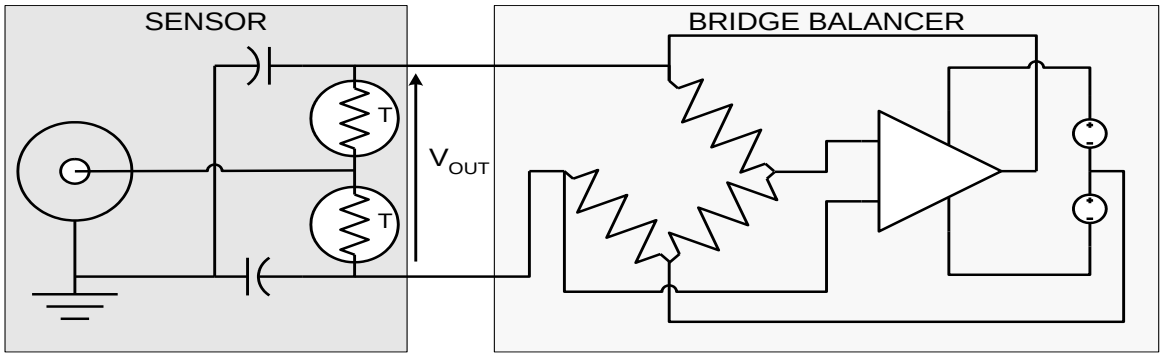

Figure 1 - Thermistor Mount and Bridge Balancing with the 1830A

Thermistor mounts like the TEGAM Model M1130A or the Agilent 478A with option H75 or H76 operate at a DC Resistance of 200 Ω which has an RF impedance of 50 Ω and a negligible Γ_{Load} (zero).[1] With the ability to change the thermistor mount reference resistance to 100 Ω the RF impedance becomes 25 Ω giving a nominal Γ_{Load} of 0.33. The effective efficiency of the thermistor mount remains constant at both 200 Ω and 100 Ω so the power ratio can be measure accurately.

[1] The H75 and H76 are options for the 478A that represent optimized performance for VSWR. Specifically, from 1 MHz to 1 GHz maximum, VSWR is less than 1.3:1, except at 50 MHz, maximum VSWR of 1.05:1.

Calculating Output SWR

Equipment:

- TEGAM 1830A RF Power Meter
- Thermistor Mount
  - TEGAM M1130A
  - Agilent 478A with options H85 or H76
- DUT Power Meter with 50 MHz, 1 mW Reference Port

Procedure:
The following procedure should be used for solving Output SWR:

1. Power ON all equipment and allow proper warm up time for each. If using a temperature compensated thermistor mount allow for proper temperature stabilization.[2]
2. Connect thermistor mount to 1830A
   a. For M1130A use the following cables
      i. TEGAM CA-7-48 (Sensor Cable)
      ii. TEGAM CA-10-48 (Heater Cable)
   b. For 478A use cable TEGAM CA-6-48 (Sensor Cable)
3. Manually configure the 1830A for selected thermistor mount.[3]
4. Make sure the 50 MHz reference is turned off prior to connecting the thermistor mount.[4]
5. Connect thermistor mount to 50 MHz Reference Output Connection.
6. Record RHO_{200} the S22 Magnitude of the thermistor mount at 50 MHz at 200 Ω[5].
   a. For an M1130A this value is available on the calibration report
   b. For a 478A use the value of .0012 as an estimated value
7. Record RHO_{100} the S22 Magnitude of the Thermistor Mount at 50 MHz at 100 Ω.
   a. For an M1130A use the value of .33 as an estimated value
   b. For a 478A us the value of .33 as an estimated value
8. Verify the 1830A reference resistor is configured for 200 Ω.
9. Zero the 1830A.
10. Turn on the 50 MHz 1mW reference on the DUT Power Meter.
11. Record the power level from the front panel of the 1830A.
12. Turn off the 50 MHz 1mW reference on the DUT power meter.
13. Configure the 1830A reference resistor to 100 Ω.
14. Repeat steps 10-12.
15. Calculate M using the following equation.

$$M = \frac{P_{200}\left(1-|RHO_{100}|^2\right)}{P_{100}\left(1-|RHO_{200}|^2\right)}$$

[2] Verify on 1830A front panel that heating is complete and unit has a stable zero.
[3] Please refer to 1830A User Manual for configuring a Temperature Compensated Thermistor Mount vs. an Agilent 478A Thermistor Mount.
[4] Please refer to the DUT Power Meter Manual for operating instructions.
[5] Gamma of the load is a complex value; however we can give a sufficiently accurate answer providing the phase angles are within a reasonable range. For this reason all calculations in this application note will only use RHO portion of Gamma.

16. Using the Value for M calculate the output voltage coefficient using the following equation.

$$|\Gamma_s| = \frac{(2|RHO_{200}|M-2|RHO_{100}|)\pm\sqrt{(2|RHO_{100}|-2|RHO_{200}|M)^2-4(|RHO_{200}|^2M-|RHO_{100}|^2)(M-1)}}{2(|RHO_{200}|^2M-|RHO_{100}|^2)}$$

17. Calculate the output SWR using the following equation.

$$SWR = \frac{(1+|\Gamma_s|)}{(1-|\Gamma_s|)}$$

Worked Example of Output SWR

For this example the DUT was an Agilent E4418B Power Meter. Output SWR is required to be maximum 1.06. A TEGAM 1830A with a M1130A were also used for this example. The output SWR is 1.029.

Recorded Values	**Value**
Power(mW) (200 ohms Ref Resistor)	0.9936
Power(mW) (100 ohms Ref Resistor)	0.8939
Fixed Values (From Thermistor Mount calibration data)	
RHO (200 ohms Ref Resistor)	0.0014
RHO (100 ohms Ref Resistor)	0.33
Calculations	
Calculate Factor M	0.990485764
Calculate Output voltage reflective coefficient(+)	0.01451123
Calculate Output voltage reflective coefficient(-)	6.020735385
Output SWR(+)	1.029449814
Output SWR(-)	-1.39834802

NOTE: A downloadable spreadsheet with all formulas is located in TEGAM Forums.
http://geneva.tegam.com/forums/

Calculating Output SWR: Programming Example

The following is the exact procedure we just followed manually; however, in this procedure we have included all the command necessary to complete the procedure remotely with third party software such as VB or LabVIEW. The necessary command will be **BOLD**. Before communicating with the 1830A we must first understand how the 1830A can be communicated with and how to set up a proper command structure.

1830A Remote Operation

Remote control of the 1803A is available via two different methods. A command structure that allows for the control and query of all operations is available through Universal Serial Bus (USB) and TCP/IP. Commands are text and not case sensitive. Commands are made up of multiple words or values sent as a space delimited string.

NOTE: Whether using SET or GET it is always necessary to read back after each command. The 1830A returns back an error code after every SET and every GET. If the buffer is not read after each command improper results will be returned.

1830A Command Structure

GET and SET variables by following the structure below.

GET {VARIBLE NAME} {ITEM}
Retrieve a system variable value.

SET {VARIBLE NAME} **CV** {VALUE}
Set the current value of the variable to the passed input value.

Example:
To retrieve the current loaded calibration factor we would use the following command structure.

GET K_1 CV

1830A Returns 00:1.0000
00: = No Error
1.0000 is the calibration factor

SET COMPENSATION_MODE CV 0

1830A Returns 00:
00: = No Error

The following is an example of how to use the 1830A remotely to calculate output SWR. This example can be used in any programming language that is capable of communicating with test and measurement equipment.

Equipment:

- TEGAM 1830A RF Power Meter
- Thermistor Mount
  - TEGAM M1130A
  - Agilent 478A with options H85 or H76
- DUT Power Meter with 50 MHz, 1 mW Reference Port (For this example use Agilent E4418B)

Procedure:
The following procedure should be used for solving Output SWR:

1. Power ON all equipment and allow proper warm up time for each. If using a temperature compensated thermistor mount allow for proper temperature stabilization.
2. Connect thermistor mount to 1830A
   a. For M1130A use the following cables
      i. TEGAM CA-7-48 (Sensor Cable)
      ii. TEGAM CA-10-48 (Heater Cable)
   b. For 478A use cable TEGAM CA-6-48 (Sensor Cable)
3. Use the following commands to configure 1830A for connection to M1130A or 478A.
   a. SET COMPENSATION_MODE CV 0
      i. 0 = No Compensation[6] (TEGAM Mounts)
      ii. 2 = 432 Bias Comp[7] (Agilent Mounts)
   b. Make sure to read the return after the SET COMPENSATION_MODE CV 0 command to clear read buffer
4. Make sure the 50 MHz reference is turned off prior to connecting the thermistor mount.
   a. OUTP:ROSC OFF
5. Connect thermistor mount to 50 MHz Reference Output Connection.
6. Record RHO_{200} the S22 Magnitude of the thermistor mount at 50 MHz at 200 Ω.
   a. For an M1130A this value is available on the calibration report
   b. For a 478A use the value of .0012 as an estimated value
7. Record RHO_{100} the S22 Magnitude of the Thermistor Mount at 50 MHz at 100 Ω.

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[6] ***No Compensation*** – To be used with TEGAM thermistor mounts such as the F1130A. The TEGAM thermistor mount is a type of bolometer whose resistance decreases as a function of increasing heat associated with ambient temperature or applied power. This system also features the Model 1830A temperature control circuitry that temperature stabilizes TEGAM and Weinschel thermistor mounts. This eliminates changes in the thermistor element's resistance due to ambient temperature changes and thus isolates the causes of thermistor variation to the application of RF and DC power only. Therefore compensation for ambient temperature is not needed.

[7] ***432 Bias Comp –*** This mode assumes that a temperature-compensated mount is attached. The Bias Comp mode balances both channels just like the 432 Compatible mode, the difference is the voltmeter readings from only Channel 1 are used in the simple power equation of **$P=(V[OFF]^2 - V[ON]^2)/R$**. This method is recommended for standards lab use with 478, 486, 8478 series thermistor mounts, because the errors from only one channel are transferred, while in a lab the mount environment can be stabilized using insulation.

a. For an M1130A use the value of .33 as an estimated value
b. For a 478A us the value of .33 as an estimated value

8. Verify the 1830A reference resistor is configured for 200 Ω.
   a. **SET R_1 CV 200**
   b. **Make sure to read the return after the SET R_1 CV 200 command to clear read buffer**
9. Zero the 1830A.
   a. **Before issuing the rezero command wait minimum 5 seconds for mount to settle at 200 Ω.**
   b. **SET REZERO_SYSTEM CV 1**
   c. **Make sure to read the return after the REZERO_SYSTEM CV 1command to clear read buffer**

NOTE: A 49: will be returned after a rezero. 49 is a system rezero warning.

10. Turn on the 50 MHz 1mW reference on the DUT Power Meter.
    a. **OUTP:ROSC ON**
11. Record the power level from the front panel of the 1830A.
    a. **Before issuing the GET POWSUB_1 CV command wait minimum 5 seconds for mount to settle power measurement.**
    b. **GET POWSUB_1 CV**
    c. **Read return buffer.**
12. Turn off the 50 MHz 1mW reference on the DUT power meter.
    a. **OUTP:ROSC OFF**
13. Configure the 1830A reference resistor to 100 Ω.
    a. **SET R_1 CV 100**
    b. **Make sure to read the return after the SET R_1 CV 100 command to clear read buffer**
14. Repeat steps 10-12.
15. Calculate M using the following equation.

$$M = \frac{P_{200}\left(1-|RHO_{100}|^2\right)}{P_{100}\left(1-|RHO_{200}|^2\right)}$$

16. Return 1830A to 200 Ω.
    a. **SET R_1 CV 200**
    b. **Make sure to read the return after the SET R_1 CV 200 command to clear read buffer**

Having confidence that your 50 MHz reference port SWR is within specifications is important. By adhering to the procedures while using the TEGAM Model 1830A RF Power Meter and a calibrated thermistor mount like the TEGAM Model M1130A, you can be certain that your 50 MHz reference SWR is within the manufactures tolerance.